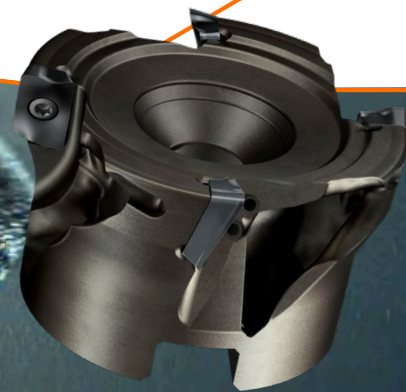


# TITANIUM POWDER BY SANDVIK

THE ADDITIVE ADVANTAGE



80%  
REDUCED WEIGHT

200%  
INCREASED  
PRODUCTIVITY

22 OCTOBER, 2019  
SANDVIKEN, SWEDEN



# AGENDA

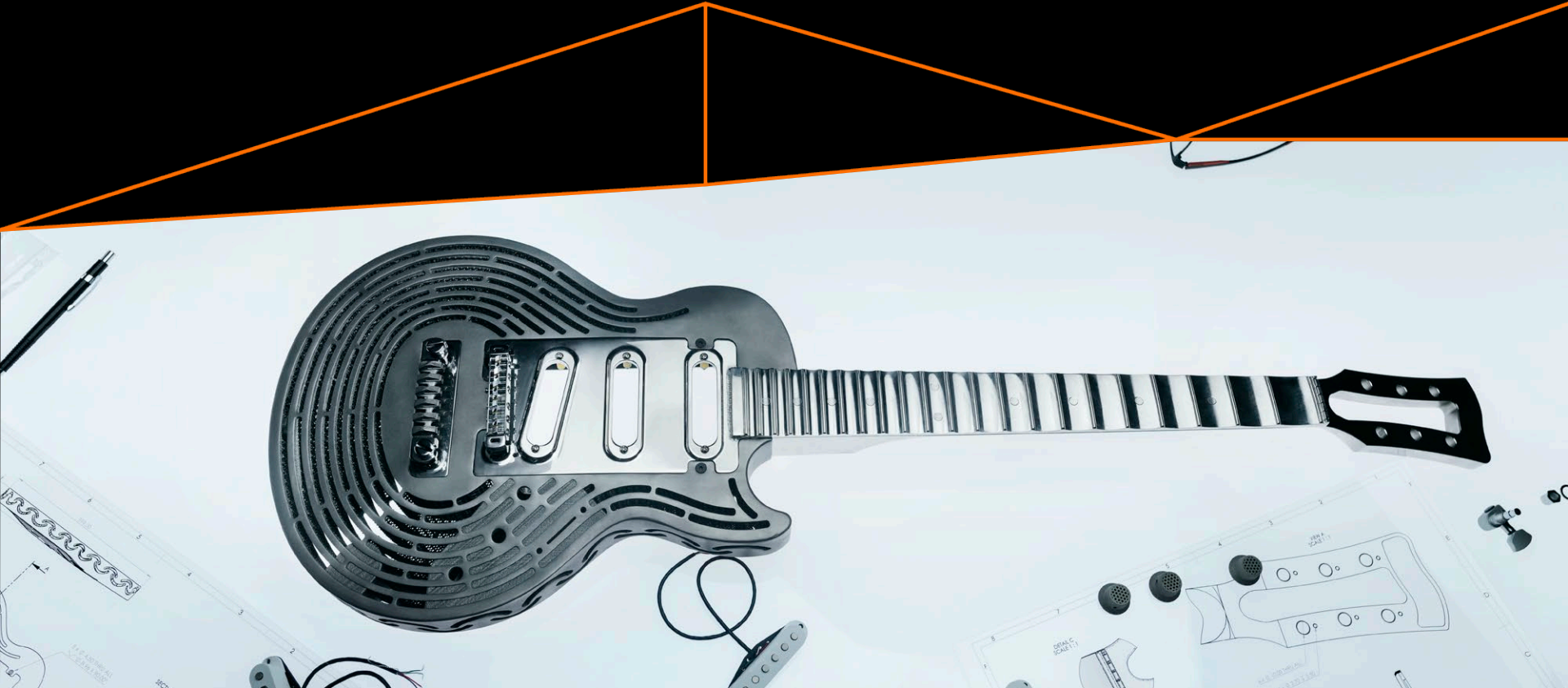
## TITANIUM POWDER BY SANDVIK – THE ADDITIVE ADVANTAGE

13:30 - 13:45	SAFETY FIRST AND WELCOME!	Kristian Egeberg
→ 13:45 - 14:10	INTRODUCTION TO SANDVIK – AND TITANIUM AS AN ELEMENT	Mikael Schuisky
14:10 - 14:35	TITANIUM AND NICKEL POWDER PRODUCTION BY SANDVIK	Martin Mueller
14:35 - 15:00	TITANIUM AND NICKEL POWDER BY SANDVIK – THE ADDITIVE ADVANTAGE	Keith Murray
15:00 - 15:20	SWEDISH "FIKA"	All
15:20 - 15:40	AM-PROCESSING OF TITANIUM	Harald Kissel
15:40 - 16:10	BEAMIT – EXPERIENCE FROM AM OF TITANIUM COMPONENTS	Michele Antolotti and Martina Riccio
16:10 - 16:25	TITANIUM COMPONENTS FOR GSD E-BIKES	Zach Krapfl
16:25 - 16:40	LIGHTWEIGHT COROMILL® 390	Matts Westin
16:40 - 16:55	OSSDSIGN – IMPLANTS FOR BONE REGENERATION	Kajsa Björklund
16:55 - 17:10	SWISS CENTER OF MANUF. TECHNOLOGIES FOR MEDICAL	Harald Kissel
17:10 - 17:30	SUMMARY, CONCLUSIONS AND KEY TAKE-AWAYS	Mikael Schuisky & All
18:00	DINNER @ BRUKSMÄSSEN	All





# INTRODUCTION TO SANDVIK AND SANDVIK ADDITIVE MANUFACTURING





# SANDVIK GROUP

WORLD LEADING POSITION IN...

METAL  
CUTTING

MINING  
AND ROCK  
TECHNOLOGY

ADDITIVE  
MANUFACTURING

ADVANCED MATERIALS  
TECHNOLOGY

42,000  
EMPLOYEES

100  
BILLION SEK  
IN REVENUES

50  
R&D CENTERS  
GLOBALLY

SALES IN OVER  
160

COUNTRIES  
AROUND THE GLOBE

3.5 BILLION SEK  
ANNUAL R&D  
INVESTMENT

5,900  
ACTIVE PATENTS



# LEADING AND WELL ESTABLISHED CAPABILITIES

## ACROSS THE AM VALUE CHAIN



### MATERIALS

- World leader in metallurgy
- Powder expert
- Leading in metal powder for AM
- Widest range of Osprey™ AM-alloys



### MANUFACTURING

- 3D design
- Several AM processes
- Center of Digital Excellence



### POST PROCESSING

- World leader in metal cutting
- Sintering and HIP
- Other post processing



### RELATED CAPABILITIES

- Testing and characterization
- Traceability and documentation
- Component know-how
- Customer base
- Distribution network



# ADDITIVE BY SANDVIK

## PLAN IT – PRINT IT – PERFECT IT

### PLAN IT



### PRINT IT



### PERFECT IT

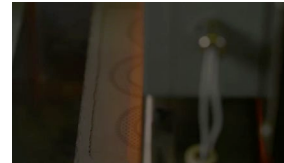


### OUR OFFERING:



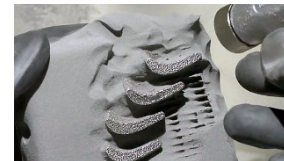
#### Advisory services

We take you from idea to prototype – or serial production.



#### Manufacturing services

From rapid prototyping to serial production, we offer full service production of your component.



#### Metal powder

We offer the widest range of powder alloys for additive manufacturing around and can even customize materials.



# 2019

## SANDVIK ADDITIVE MANUFACTURING

**JANUARY**



The **Powder Division** is **merged** with the **Additive Manufacturing Division** in Sandvik.

SANDVIK

SANDVIK

SANDVIK

SANDVIK

SANDVIK

SANDVIK

SANDVIK

SANDVIK

**MARCH**



**Launch of Coromill® 390** in titanium, with 80% reduced weight – and increased productivity by up to 200%.

**APRIL**

The **smash-proof guitar in Ti** is launched. The film has so far been seen by 41 million people.



**JULY**

**Sandvik** announces a major investment in the strategic partner **BEAMIT** in Italy.



**OCTOBER**

**Sandvik** inaugurates state-of-the-art **titanium powder plant** in Sandviken, Sweden.



**JUNE**



**ADDITIVE NEXT** – a joint AM-event by **Sandvik and Siemens** – takes place in Högbö, Sweden.

**SEPTEMBER**



**Increased AM-powder production** capabilities with a **new tower** – and approved investment in Aluminum powder capabilities in Neath, UK.

**OCTOBER**

The inch assortment of the of Coromill® 390 is launched.

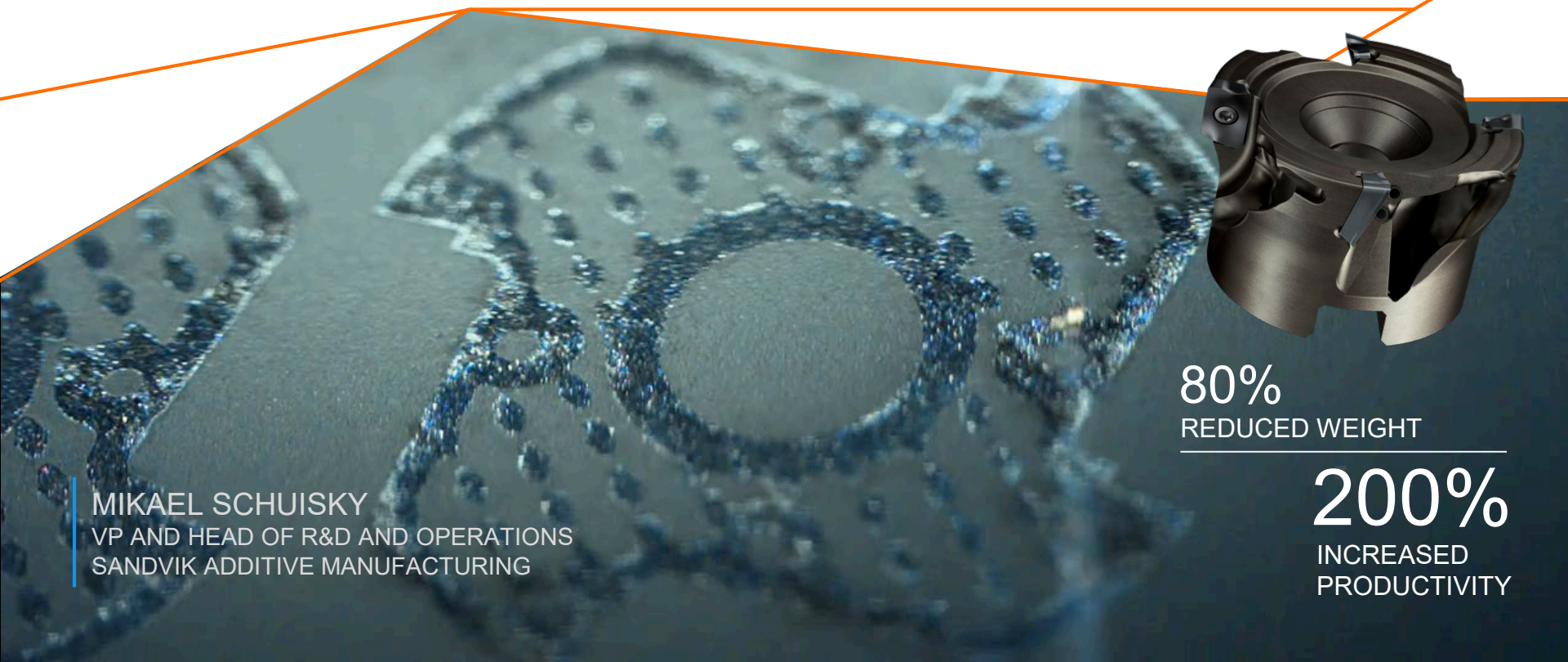


**NOVEMBER**  
**formnext**

**BEAMIT and Sandvik** will join forces and co-exhibit at **Formnext** in Frankfurt.



# INTRODUCTION: TITANIUM AS AN ELEMENT



80%  
REDUCED WEIGHT

200%  
INCREASED  
PRODUCTIVITY

MIKAEL SCHUISKY  
VP AND HEAD OF R&D AND OPERATIONS  
SANDVIK ADDITIVE MANUFACTURING



# PHYSICAL PROPERTIES OF TITANIUM

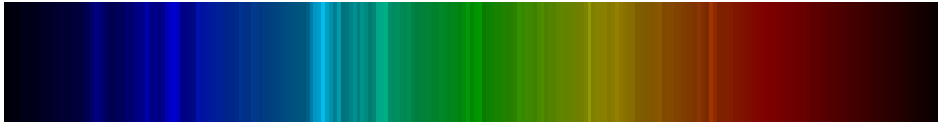
- Melting Point 1668 °C
- Boiling point 3287 °C
- Density 4.506 g/cm<sup>3</sup>
- Heat of fusion 14.15 kJ/mol
- Heat of Vaporization 452 kJ/mol
- Molar heat capacity 25.06 J/(mol\*K)





# ATOMIC PROPERTIES OF TITANIUM

- Oxidation states -2, -1, +1,+2,+3, **+4**  
(an amphoteric oxide)
- Electronegativity 1.54 (Pauling Scale)
- Atomic radius 147 pm
- Covalent radius  $160 \pm 8$  pm
- Natural occurring Isotopes  $^{46}\text{Ti}$ ,  $^{47}\text{Ti}$ ,  **$^{48}\text{Ti}$** ,  $^{49}\text{Ti}$  &  $^{50}\text{Ti}$



SPECTRAL LINE OF TITANIUM

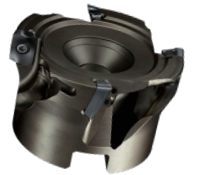
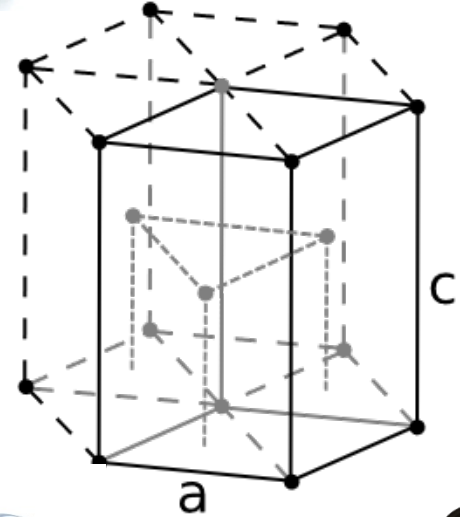




# OTHER PROPERTIES

## TITANIUM

- Hexagonal closed packed (hcp)
- Thermal expansion  $8.6 \mu\text{m}/(\text{m}^*\text{K})$
- Thermal conductivity  $21.9 \text{ W}/(\text{m}^*\text{K})$
- Electrical resistivity  $420 \text{ n}\Omega^*\text{m}$
- Youngs modulus  $116 \text{ GPa}$
- Shear modulus  $44 \text{ GPa}$
- Bulk modulus  $110 \text{ GPa}$
- Vickers hardness  $830\text{-}3420 \text{ MPa}$





# THE HISTORY OF TITANIUM





# 1791

WILLIAM GREGOR

Clergymen and amateur geologist  
**William Gregor** successfully isolated  
titan oxide from the mineral Ilmenite ( $\text{FeTiO}_3$ ).





# 1795

## MARTIN HEINRICH KLAPROTH

Discovered the same material in mineral Rutile ( $\text{TiO}_2$ ). He named it **Titanium** after the Titans of Greek mythology.





# 1825

## JÖNS JACOB BERZELIUS

Metallic titanium was **first produced in an un-pure form** by the Swede Jöns Jacob Berzelius.

“THE FATHER OF THE  
SWEDISH CHEMISTRY”





# 1910

MATTHEW A. HUNTER

Pure metallic titanium (99.9%) was first prepared in 1910 at Rensselaer Polytechnic Institute by heating  $\text{TiCl}_4$  with sodium at 700–800 °C under great pressure in a sealed batch process today known as **the Hunter Process**.



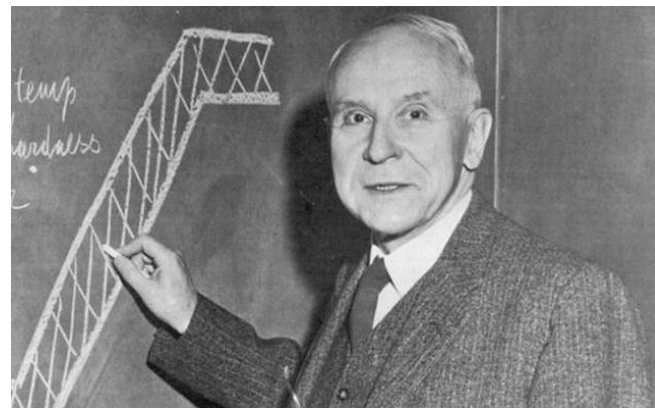


# 1940

WILLIAM J KROLL

The **Kroll process** is a pyrometallurgical industrial process used to produce metallic titanium.

- 1)  $\text{FeTiO}_3 + \text{C} \Rightarrow \text{Fe} + \text{TiO}_2 + \text{CO}$
- 2)  $\text{TiO}_2 + 2\text{C} + 2\text{Cl}_2 \Rightarrow \text{TiCl}_4 + 2\text{CO}$
- 3)  $\text{TiCl}_4 + 2\text{Mg} \Rightarrow \text{Ti} + 2\text{MgCl}_2$





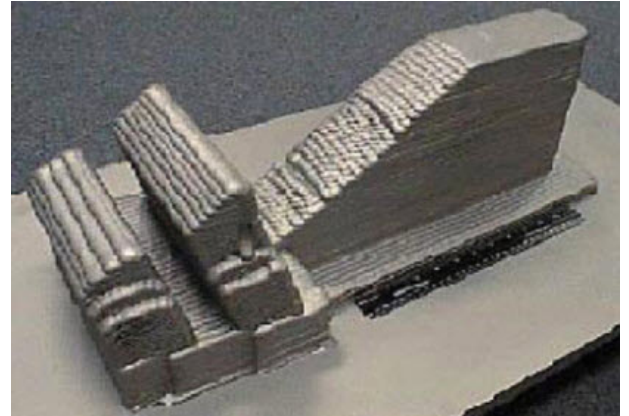
# 1997

## AEROMET


AeroMet a subsidiary of MTS Systems Corp developed a process call **laser additive manufacturing (LAM)** which used a high power laser and **titanium powders**.

"We're one of the first wave of companies in the new industry of direct-metal deposition," said Frank Arcella, president of AeroMet.  
"The unique niche we hold is that titanium is so hard to work with."

MINNEAPOLIS/ST PAUL BUSINESS JOURNAL MAY 24<sup>TH</sup>, 1998.





A close-up, high-contrast photograph of a titanium mechanical component, likely a turbine or engine part, being machined. The component is dark and metallic, with a central circular opening. The background is blurred, showing other parts of the machinery. The text "PREVIOUS TITANIUM APPLICATIONS BY SANDVIK" is overlaid in white, bold, sans-serif capital letters.

# PREVIOUS TITANIUM APPLICATIONS BY SANDVIK



# TITANIUM

## USE WITHIN SANDVIK

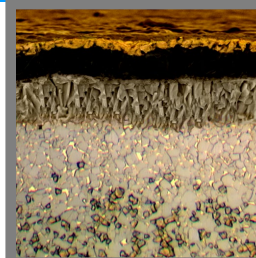


**1964** Sandvik starts the production alloys of reactive metals i.e. Zr and Ti.

At Sandvik we since the **1980's** produces Ti tubes for aerospace applications.

Ti is use as minor alloying element by Sandvik in several alloys for instance 18Ni300.

**1969** Sandvik Coromant introduced TiC coated inserts and today hard and wear resistant titanium coatings like TiAlN, Ti(C,N) and TiN are used on most inserts.



TiN  
 $\text{Al}_2\text{O}_3$   
Ti (C,N)





# TITANIUM ABUNDANCE

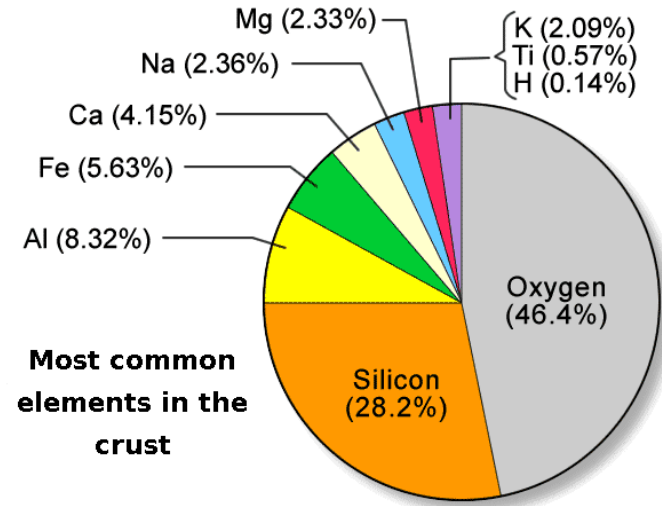




# TITANIUM ABUNDANCE

THE 9<sup>TH</sup> MOST COMMON ELEMENT IN THE EARTH CRUST (0.57%)

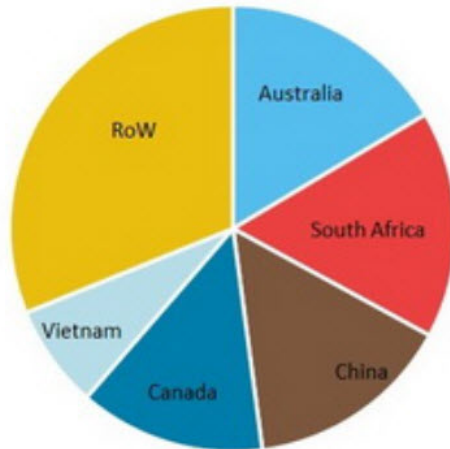
- Primarily found in the minerals
  - Rutile ( $\text{TiO}_2$ )
  - Ilmenite ( $\text{FeTiO}_3$ )
  - Sphene ( $\text{CaTiSiO}_5$ ).



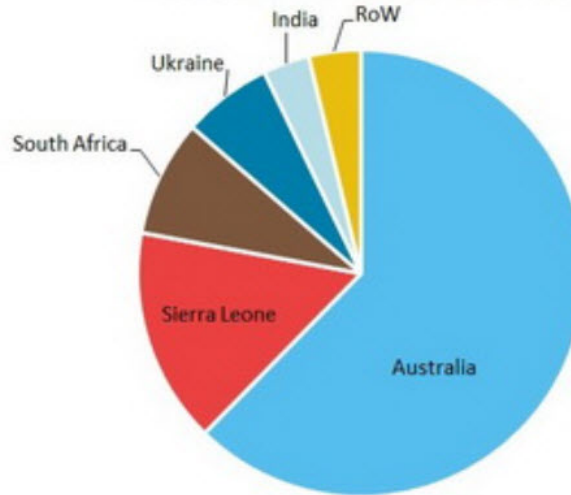


# TOP PRODUCERS OF TI MINERALS

**Ilmenite Mine Production Globally**



**Rutile Mine Production Globally**





# PRODUCTION OF TITANIUM SPONGE

Metallic titanium sponge is today mainly produced with the Kroll process.

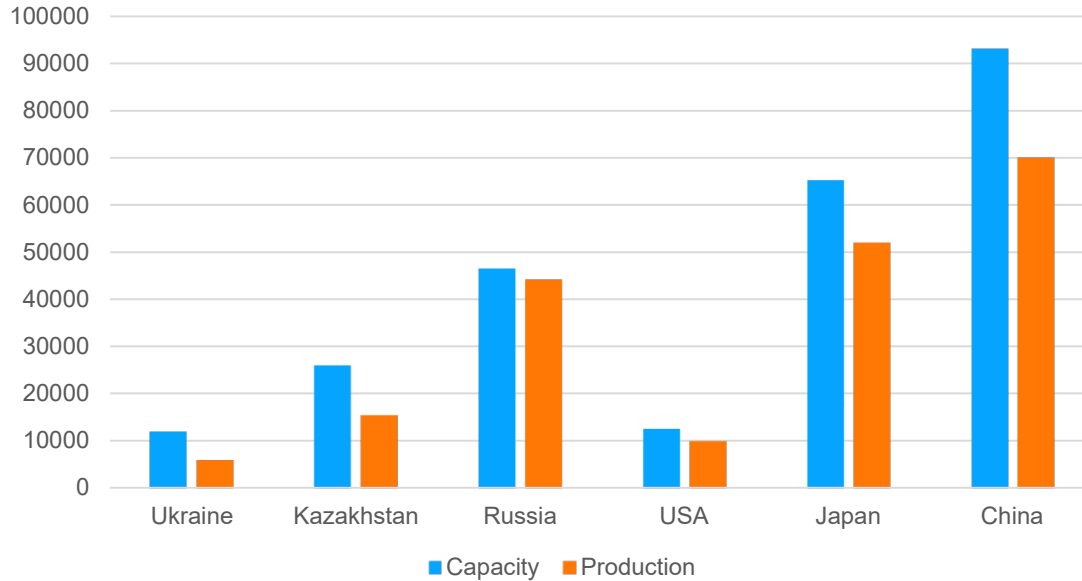
- 1)  $\text{FeTiO}_3 + \text{C} \Rightarrow \text{Fe} + \text{TiO}_2 + \text{CO}$
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# TITANIUM SPONGE PRODUCTION (2018)

Titanium Sponge Capacity vs Production



## CAPACITY UTILIZATION

Ukraine	50%
Kazakhstan	60%
Russia	95%
USA	79%
Japan	80%
China	75%